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### Authors

Oldach, Maureen S  
Gunther-Harrington, Catherine T  
Balsa, Ingrid M  
et al.

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# Aberrant migration and surgical removal of a heartworm (*Dirofilaria immitis*) from the femoral artery of a cat

Maureen S. Oldach<sup>1</sup> | Catherine T. Gunther-Harrington<sup>2</sup>  | Ingrid M. Balsa<sup>3</sup> |  
 Ehren M. McLarty<sup>1</sup> | Kyle A. Wakeman<sup>1</sup> | Kathryn L. Phillips<sup>3</sup> |  
 Juhana Honkavaara<sup>1</sup> | Lance C. Visser<sup>2</sup>  | Joshua A. Stern<sup>2</sup>

<sup>1</sup>William R. Pritchard Veterinary Medical Teaching Hospital, University of California-Davis, Davis, California

<sup>2</sup>Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California-Davis, Davis, California

<sup>3</sup>Department of Surgical and Radiological Sciences, School of Veterinary Medicine, University of California-Davis, Davis, California

## Correspondence

Catherine Gunther-Harrington, DVM, DACVIM (Cardiology), University of California-Davis, Davis, CA 95616.  
 Email: cgharrington@ucdavis.edu

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A cat was evaluated for an acute-onset of right pelvic limb paresis. Thoracic radiographs revealed normal cardiac size and tortuous pulmonary arteries. Abdominal ultrasound identified a heartworm (HW) extending from the caudal abdominal aorta into the right external iliac artery and right femoral artery. The cat was HW-antigen positive. Echocardiography revealed a HW within the right branch of the main pulmonary artery and evidence of pulmonary hypertension. An agitated-saline contrast echocardiogram revealed a small right to left intracardiac shunt at the level of the atria. Surgical removal of the HW was performed with no substantial postoperative complications. There was return of blood flow and improved motor function to the limb. The cat remains mildly paretic on the affected limb with no other clinical signs.

## KEYWORDS

arterial, feline, heart, pulmonary hypertension, thromboembolism

## 1 | CASE DESCRIPTION

A 4-year-old, 4.1 kg female-spayed Siamese cat was presented to the University of California, Davis Veterinary Medical Teaching Hospital (UCD-VMTH) for evaluation of acute-onset right pelvic limb (RPL) paresis. Three years before presentation, the cat was evaluated for a cough while living in Texas. HW antibody test was reportedly positive and it received treatment with prednisolone (unknown dose). The cough resolved and it had been asymptomatic in the interim. One day before

presentation to UCD-VMTH, it was presented to an emergency clinic for acute RPL lameness. Thoracic radiographs were performed because of suspicion of a cardiogenic thromboembolism, and revealed tortuous pulmonary arteries and a diffuse bronchial pattern. Considering the cat's previous HW exposure, heartworm disease (HWD) was considered a likely cause and a point of care HW antigen test (Snap RT, IDEXX Laboratories, Portland, Maine) was positive. An abdominal ultrasound revealed a linear mobile structure in the caudal aorta and right external iliac artery suggestive of a HW. The cat was referred to UCD-VMTH for further evaluation.

On presentation, the cat was bright and alert, with a heart rate of 210 beats per minute. Rectal temperature was 101.4°F. Respiratory effort was mildly increased with handling and respiratory rate was 44 breaths per minute. Cardiac auscultation revealed a grade I/VI right parasternal systolic heart murmur and a split S2 heart sound. The

**Abbreviations:** ASD, atrial septal defect; CT, computed tomography; HW, heartworm; HWD, heartworm disease; LV, left ventricular; PH, pulmonary hypertension; PFO, patent foramen ovale; RPL, right pelvic limb; UCD-VMTH, University of California, Davis Veterinary Medical Teaching Hospital.

This work was completed at the William R. Pritchard Veterinary Medical Teaching Hospital at the University of California, Davis.

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femoral pulse was not palpable in the RPL and was normal in the left pelvic limb. The cat had a RPL non-weight-bearing monoparesis, with moderate motor function to the tarsocrural joint. The nailbeds of the RPL were light pink, paler than the contralateral limb, and there was marked poikilothermia of the limb. There was muscle fasciculation of the thigh musculature and the cat was resistant to manipulation of the RPL. Examination of the contralateral limb was normal. Given concern for a high worm burden, a Knott's microfilarial test was performed and was negative.

An echocardiogram (2-dimensional, M-mode, and color and spectral Doppler) was performed. A double-walled linear structure consistent with a HW was observed in the visible right branch of the main pulmonary artery. A subjectively dilated main pulmonary artery suggested the presence of pulmonary hypertension (PH). There was mild dynamic right ventricular outflow tract obstruction (velocity 2.28 m/s), the cause of the cat's murmur. There was trace tricuspid regurgitation and no evidence of pulmonic insufficiency on color Doppler assessment; therefore, estimation of pulmonary arterial pressure was not possible. Transmitral spectral Doppler revealed a myocardial relaxation delay. The diastolic diameter of the interventricular septum was equivocally increased (5.5 mm) and mild systolic anterior motion of the septal leaflet of the mitral valve without significant LV outflow obstruction was noted. Remaining measurements were within normal limits. The left ventricular (LV) wall measures and evidence of impaired relaxation might represent occult cardiomyopathy or could have resulted from PH and LV underfilling. Agitated-saline contrast injection revealed the presence of mild right atrial to left atrial shunting consistent with increased right atrial pressure further supporting PH. A defect in the atrial septum was not clearly identified on 2-dimensional echocardiogram but a small atrial septal defect (ASD) or patent foramen ovale (PFO) was suspected given the location of the shunting.

Abdominal ultrasound revealed a structure with parallel hyperechoic borders and a hypoechoic center consistent with a HW (Figure 1, Supporting Information Video 1), extending from the caudal abdominal aorta (roughly 3–4 cm proximal to the aortic trifurcation) into the right external iliac and right femoral arteries, ~1/4–1/3 down the length of the femur. Color Doppler interrogation revealed that blood flow gradually decreased adjacent to the worm and was not identified distal to the worm. Blood flow was present within the femoral vein.

Sixteen-slice thoracic and pelvic limb computed tomography (CT) with contrast were performed under general anesthesia to assess the cat's parasite burden and the affected limb's viability. The caudal right and left main pulmonary arteries were enlarged and tortuous. There were no obvious filling defects suggestive of worms within the pulmonary vasculature. There were multifocal interstitial to alveolar infiltrates throughout the lung lobes and some infiltrates were perivascular. These changes were the most severe on the right. These findings were interpreted as being consistent with dirofilariasis with pneumonitis/verminous pneumonia and possible thromboembolic disease. On RPL CT with contrast (Figure 2), the right femoral artery did not fill with contrast distal to the vascular lacuna and the proximal segment was dilated in comparison to the contralateral limb. The musculature surrounding and distal to the stifle joint was swollen with lack of enhancement on post-



**FIGURE 1** Ultrasound image of the HW within the right external iliac artery. The white bar represents 1 cm in depth. The denotation \* represents the lumen of the femoral artery proximal to the HW. Distally arrowheads demarcate the outer border of the worm

IV contrast imaging. These findings supported pelvic limb ischemia secondary to arterial occlusion from the HW. The cat recovered uneventfully from anesthesia.

The cat was hospitalized and treated with IV opioid pain management (oxymorphone 0.05 mg/kg IV q4–6h [Endo Pharmaceuticals, Newark, Delaware], transitioned to buprenorphine 0.015 mg/kg IV q6–8h [Par Pharmaceuticals Companies, Spring Valley, New York]), clopidogrel 18.75 mg PO q24h (Dr. Reddy's Laboratories Limited, Bachupally, India), prednisolone 2.5 mg PO q12h (Lloyd, Shenandoah, Iowa), and doxycycline 50 mg PO q12h (Lupin Pharmaceuticals, Baltimore, Maryland). It was monitored closely to establish if it would regain limb perfusion without further intervention. It remained stable over the next 24 hours but perfusion parameters of the feline RPL remained static. Forty-eight hours after presentation, it was anesthetized for surgical removal of the arterial HW. It was premedicated with diphenhydramine (2 mg IV; West-Ward Pharmaceuticals, Eatontown, New Jersey) before induction. Anesthesia was maintained with a <1% end-tidal concentration of isoflurane (Primal Enterprises, Andhra Pradesh, India) and a continuous rate infusion of dexmedetomidine (0.5 mcg/kg/h; Dexdomitor, Orion Corporation, Espoo, Finland). It breathed spontaneously throughout the procedure. A medial approach to the right femoral artery was performed and the femoral artery was isolated. By intraoperative ultrasound guidance, a 1 cm incision was made with a #11 blade into the femoral artery just distal to the end of the HW. DeBakey forceps were used to grasp the worm and extract it from the vessel (Supporting Information Video 2). An intact, 13 cm HW was removed. The arteriotomy was permitted to hemorrhage for 60 seconds after worm removal during which appropriate blood flow was appreciated. A rumel tourniquet was then applied and released to assess flow; no blood flow from the arteriotomy site was noted. The artery was retroflushed with saline



**FIGURE 2** A dorsal plane post-contrast CT of the RPL is shown. The musculature distal to and surrounding the stifle are swollen with a marked lack of contrast enhancement (\*), suggestive of limb ischemia. There is contrast attenuation noted within the proximal femoral artery demarcated by "<" suggestive of thrombosis

resulting in no improvement in blood flow; arterial spasm was suspected. The arteriotomy was closed with 6-0 polydioxanone in a simple continuous pattern. The SC and skin incisions were closed with 4-0 poliglecaprone. The cat remained stable throughout the procedure and recovered from anesthesia uneventfully. The worm was submitted for analysis with the UCD-VMTH Parasitology Laboratory and was confirmed to be a non gravid female *Dirofilaria immitis* nematode.

Two-hours postoperatively the cat was assessed to have regained blood flow to the RPL based on the presence of a palpable dorsal pedal pulse and normalization of palpable distal limb temperature. Motor function improved during this time as well, with voluntary movement at the tarsocrural joint, however it remained unable to place its paw in

a plantigrade position during ambulation. Arterial blood gas after surgery revealed hypoxemia (PaO<sub>2</sub> 60.3 mm Hg; ref. >80 mm Hg) with a mild hypercapnia (PaCO<sub>2</sub> 38.5 mm Hg; ref. 28-34 mm Hg) when breathing room air. The hypoxemia was not responsive to oxygen supplementation (30%); the PaO<sub>2</sub> increased to only 62.4 mm Hg. The persistent hypoxemia was likely secondary to the right to left intracardiac shunt and less likely pneumonia or atelectasis give the poor response to supplementary oxygen. The cat remained tachypneic but with a normal respiratory effort during this time, with respiratory rates averaging 50 breaths per minute. Treatment with sildenafil (Amneal Pharmaceuticals, Ahmedabad, India) 5 mg (1.2 mg/kg) PO q12h was initiated. It was monitored on continuous ECG for arrhythmias or alterations consistent with hyperkalemia. Postoperative serum potassium concentration remained normal (3.8–3.9 mEq/L; ref. 3.5–4.8 mEq/L) as was plasma lactate (<2 mmol/L).

Biochemical profile the day after surgery revealed increased creatinine kinase activity (279136 IU/L; ref. interval 73–260 IU/L) and AST activity (1240; ref. 7–58 IU/L) consistent with muscle damage from ischemia or from surgery and increased ALT activity (337 IU/L; ref 27–101), which could also be attributable to muscle damage.

Postoperative thoracic radiographs revealed static enlargement of the caudal lobar pulmonary arteries and a diffuse bronchial pattern likely secondary to HWD (Figure 3).

The cat was discharged 24 hours after worm removal with instruction to administer medications: sildenafil 5 mg PO q12h (Amneal Pharmaceuticals), doxycycline 50 mg PO q12h (Lupin Pharmaceuticals) for 1 month, prednisolone 2.5 mg PO q12h (Lloyd) for 2 weeks then tapered, buprenorphine 0.06 mg sublingually q8–12h (Par Pharmaceuticals Companies) as needed for pain or discomfort, clopidogrel 18.75 mg PO q24h (Dr. Reddy's Laboratories Limited), and selamectin (Revolution, Zoetis, Kalamazoo, MI) to be applied topically every 30 days. Passive range of motion of the cat's affected pelvic limb was also recommended.

The owners were contacted 4 months after discharge. The cat had enrolled in physical rehabilitation and had regained near normal function of the RPL. No other clinical signs were reported.

## 2 | DISCUSSION

HWD is uncommonly reported in cats. It has been estimated that prevalence of HWD in cats is 5%–20% of the prevalence in dogs.<sup>1</sup> Our understanding of the disease is limited because of the difficulty in diagnosing HWD in cats and the presence of a long, asymptomatic period, with many cats undergoing self-cure.<sup>2,3</sup>

Cats are infected by the subcutaneous deposition of L3 HW larvae via mosquito bites. In cats, most of the worms do not develop, as the HW is better adapted to its definitive host, the dog. After migrating and molting from L4 to L5 worms, they are carried by peripheral veins to the caudal pulmonary arteries.<sup>2</sup> Aberrant migration of the L4/L5 larvae to body cavities, eyes, and central nervous system is more common in cats compared with dogs.<sup>2,4</sup> In cats, many immature worms die, causing a profound inflammatory response, which is thought to be



**FIGURE 3** Thoracic radiographs. Left lateral (A) and dorsoventral (B) thoracic projections are shown. There is enlargement of the caudal pulmonary arteries, most notable on the right side, with a diffuse unstructured interstitial pattern and moderate diffuse bronchial pattern. These findings are supportive of pulmonary hypertension and parasitic pneumonitis

responsible for the signs seen early in the stage of HWD in cats, known as HW-associated respiratory disease, which could be mistaken for asthma.<sup>2</sup> This cat's initial clinical sign of cough 3 years before presentation along with its positive HW antibody test might have represented the acute phase of HWD in this cat. After the acute phase, there is a long asymptomatic phase. This might be because of low worm burdens as well as down-regulation of pulmonary intravascular macrophages by adult HW.<sup>5</sup> This was likely the case in the presenting cat, who had a 2–3 year asymptomatic period.

Adult HWs in cats live 2–4 years; during this time, up to 79% of cats will self-cure without further signs of disease.<sup>6</sup> However, others will develop acute respiratory distress or sudden death. Migration of a HW to the arterial vasculature has not been reported as a part of HWD in cats and this finding represents an unusual consequence of this disease. Reported cases of arterial HW migration are only in dogs, despite the fact that aberrant HW migration is more common in cats.<sup>7–13</sup> The largest reported case series included 5 dogs that

presented for pelvic limb lameness and paresis, with or without evidence of ischemic tissue necrosis. All these dogs were diagnosed with multiple adult HWs within various arteries, including femoral, external iliac, and caudal abdominal aorta. Most presentations were chronic and progressive.<sup>10</sup> The proposed mechanisms for arteriolar migration in dogs include aberrant migration of the L5 worms or relocation of adult worms via a right to left cardiac shunting lesion. Of the aforementioned case reports, only 2 dogs had identifiable right to left shunts, including 1 aorticopulmonary window and 1 PFO.<sup>7–13</sup> Lack of right to left shunts in some cases, along with a chronic progressive history support aberrant migration of juvenile worms as the likely etiology.

This cat acutely presented with ischemia-induced hind-limb monoparesis and had a right to left intracardiac shunting lesion (PFO or secundum ASD). Given this cat had a right to left shunting lesion and sudden-onset clinical signs, an acute migration of an adult worm is suspected. Alternatively, it is possible there was relocation of an L5 worm to the systemic arterial system either through the intracardiac shunt or via tissue migration. Then maturity and growth resulted in acute femoral arterial occlusion.

Despite a similar presentation to that of feline aortic thromboembolism, echocardiography ruled out cardiomyopathy as the etiology of a thromboembolism and ultrasound identified an arterial HW as the cause of this cat's signs. Given the cat failed to re-establish blood flow within 72 hours after presentation, the prognosis was considered poor. Therefore, although there was considerable concern for procedural complications of anaphylaxis and reperfusion injury, surgical removal of the worm to re-establish blood flow to the affected limb was considered the only viable treatment option. CT and echocardiographic findings were not supportive of a high worm burden. Therefore, it seemed evident that removal of the worm could improve the cat's prognosis. Arterial HW removal has not been performed in the cat, but a catheter-based approach for removal of HWs within the descending aorta, external iliac, and femoral arteries has been successfully employed in dogs but never in cats.<sup>9,10</sup> Transvenous HW removal has been performed in cats, with a high risk of mortality associated with worm breakage and resultant anaphylactic shock.<sup>14</sup> In this case, the distal location of the worm (the femoral artery) made it easily accessible, and intraoperative ultrasound allowed for identification of the worm margin. This allowed direct access to the worm from the arteriotomy site. This technique limited the need for manipulation, minimizing the risk for worm breakage. Gentle manipulation with DeBakey thumb forceps allowed for smooth retrieval of the worm without complication. Additionally, the anesthetic protocol was designed to minimize right to left shunting across the defect. Dexmedetomidine (Dexdomitor, Orion Corporation, Espoo, Finland) increased systemic vascular resistance and spontaneous breathing was preferred over positive pressure ventilation in attempt to not increase pressure across the septal defect.

There was major concern for inducing reperfusion injury with worm removal, given the evidence for marked limb ischemia noted on the CT scan. However, no signs of reperfusion injury were observed. This might in part because of the lack of vasoactive substances released with thrombosis, such as in arterial thromboembolism.



This case expands our understanding of HWD in cats, demonstrating that systemic arterial migration of HW can occur in cats, although it is likely a rare complication of the disease. Aberrant HW migration should be considered unlikely, but a possible differential diagnosis in cats who present with acute pelvic limb ischemia or paresis when there is a history or diagnostic findings suggestive of HWD. This case demonstrated successful surgical removal of an arterial HW that resulted in improved RPL motor function. Although anaphylaxis and reperfusion injury are risks of such a procedure, removal offers a viable therapeutic approach to these animals.

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## CONFLICT OF INTEREST DECLARATION

Authors declare no conflict of interest.

## OFF-LABEL ANTIMICROBIAL DECLARATION

The authors declare use of doxycycline monohydrate off-label in a cat for the treatment of *Wolbachia* spp. associated with heartworm disease.

## INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC) OR OTHER APPROVAL DECLARATION

Authors declare no IACUC or other approval was needed.

## ORCID

Catherine T. Gunther-Harrington  <http://orcid.org/0000-0003-0460-6387>

Lance C. Visser  <http://orcid.org/0000-0002-3563-0737>

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## SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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